

INDIAN RESEARCH OUTPUT IN COMPUTER SCIENCE DURING 2004-2013: A BIBLIOMETRIC ANALYSIS

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Abstract

The present study intends to analyze the Indian research output in computer science during 2004 to 2013 by obtaining data from Scopus database. This study aims to find out the Indian share, the top contributing Indian institutions, most prolific Indian authors, the preferred sources for publications by Indian authors, top countries collaborating with India and the top cited papers by Indian authors in computer science research. The results indicate that India, with 76597 publications during 2004 to 2013, stands at ninth place in computer science research. The main institutes contributing in computer science research in India are IITs, IISc and some leading universities. S. Das of Indian Statistical Institute, Kolkata is the most productive author in terms of publications. At the international front, India has maximum collaborations with United States in conducting computer science research.

Keywords: Computer science, Research productivity, Bibliometrics

1. Introduction

Computer Science is the systematic study of the feasibility, structure, expression, and mechanization of the methodical processes (or algorithms) that underlie the acquisition, representation, processing, storage, communication of, and access to information, whether such information is encoded in bits and bytes in a computer memory or transcribed in genes and protein structures in a human cell.^[1] The discipline of computer science was born in the early 1940s with the confluence of algorithm theory, mathematical logic, and the invention of the stored-program electronic computer.^[2] According to V. Rajaraman^[3] the development of computing in India is inextricably intertwined with two interacting forces: the political climate (determined by the political party in power) and the government policies mainly driven by the technocrats and the bureaucrats who acted within the boundaries drawn by the political party in power.

Understanding the growth of knowledge is a challenge especially for the information scientists. This phenomenon can be measured qualitatively and quantitatively. In this direction, bibliometrics is a set of techniques devoted to the quantitative analysis of scientific and technical activities.^[4] It provides information about the structure of

knowledge and how it is communicated.^[5] It utilizes quantitative analysis and statistics to describe patterns of publication within a given field or body of scientific literature.^[6] Bibliometrics as a technique has extensive applications in identifying the research trends in a subject, trends in authorship and collaboration in research, core periodicals, obsolescence and dispersion of scientific literature useful in estimating the comprehensiveness of secondary periodicals, studying publications by scientists, citation studies and so on. It can also be used in the identification of emerging research areas.

2. Objectives of the Study

The main objective of this study is to analyse Indian research productivity in the field of computer science. The specific objectives are to:

1. Find out the global publication share in computer science.
2. Analyze the year-wise Indian research output in computer science.
3. Study the contribution of top Indian institutions conducting research in computer science.
4. Find out the most prolific Indian authors conducting research in computer science.
5. Study the top sources preferred for publication by Indian authors in computer science.
6. Find out the top countries collaborating with India for research in computer science.
7. Study the highly cited papers by Indian authors in the field of computer science.

3. Methodology

For the present study data was obtained from Scopus database which is the world's largest abstract and citation database of peer-reviewed literature. It covers nearly 22,000 titles from over 5,000 international publishers and has about 55 million records in the scientific, technical, medical, and social sciences (including arts and humanities) field. Data on world publications on computer science was obtained for the 10 year time period from 2004-2013 and then the results were then limited to Indian publications. A different search strategy was used for finding the international collaborations and the results were analyzed manually to obtain relevant findings. The citations received by the papers since their publication were taken into consideration.

4. Analysis and Interpretation

4.1 Global Publication Share

Using Scopus database, a total record of 2306901 was obtained on computer science during ten year span of 2004 to 2013. The publication share of top 20 countries is

indicated in table 1. It was found that China and United States are the top contributing countries in computer science research with 20.95% and 19.68% share respectively. Thus, these two countries produce more than 40% of the world output in computer science research. Germany, Japan and United Kingdom are at the third, fourth and fifth position with 5.92%, 5.39% and 5.36% share respectively. The sixth, seventh and eighth position are held by France (4.58%), Canada (3.70%) and Italy (3.44%). India, with 76597 publications, has a global publication share of 3.32% and stands at the ninth position in the world.

Rank	Country	Publications	%age
1	China	483346	20.95
2	United States	453982	19.68
3	Germany	136471	5.92
4	Japan	124320	5.39
5	United Kingdom	123727	5.36
6	France	105700	4.58
7	Canada	85301	3.70
8	Italy	79411	3.44
9	India	76597	3.32
10	South Korea	76000	3.29
11	Spain	73196	3.17
12	Taiwan	68539	2.97
13	Australia	58248	2.52
14	Netherlands	39902	1.73
15	Brazil	32105	1.39
16	Singapore	28182	1.22
17	Switzerland	27873	1.21
18	Iran	27648	1.20
19	Hong Kong	26730	1.16
20	Poland	26547	1.15
World		2306901	

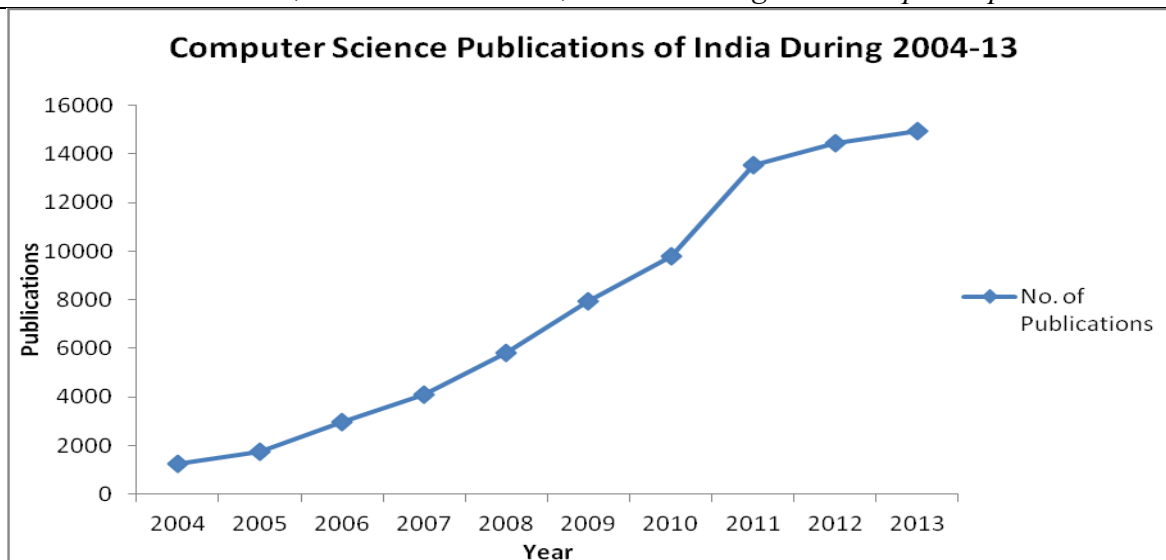
4.2 Indian Productivity in Computer Science

India published 76597 papers during 2004 to 2013 in computer science with an average of 7660 papers per year. Out of these total publications 51932 appeared as conference papers, 22837 as articles, 592 as editorials, 581 as reviews, and 358 as book chapters and the rest in other document formats (see table 3). There has been a gradual increase in the Indian publications in computer science from 1271 papers in 2004 to 14932 papers in 2013. More than half (56%) of these papers appeared during the last three years i.e. from 2011 to 2013. The 76597 papers published from 2004 to 2013 received a total of 204857 citations with an average of 2.67 citations per paper.

Table 2: Indian publication output in computer science 2004-2013

S. No.	Year	TP	Percent	TC	ACPP
1	2004	1271	1.66	14159	11.14
2	2005	1760	2.30	13596	7.73
3	2006	2979	3.89	17148	5.76
4	2007	4081	5.33	21431	5.25
5	2008	5825	7.60	23411	4.02
6	2009	7954	10.38	32817	4.13
7	2010	9782	12.77	26932	2.75
8	2011	13548	17.69	27993	2.07
9	2012	14465	18.88	18245	1.26
10	2013	14932	19.49	9125	0.61
Total		76597	100.00	204857	2.67

TP- Total Publications, TC- Total Citations, ACPP- Average Citation per Paper

**Table 3: Types of documents published**

Document Type	No. of Publications	Percentage
Conference Paper	51932	67.80
Article	22837	29.81
Editorial	592	0.77
Review	581	0.76
Book Chapter	358	0.47
Article in Press	117	0.15
Erratum	59	0.08
Book	50	0.07
Letter	39	0.05
Note	23	0.03
Short Survey	9	0.01
Total	76597	100.00

4.3 Top Productive Indian Institutions in Computer Science

Table 4 lists the most productive Indian institutions in terms of computer science publications during 2004 to 2013. These institutions have published more than 1000 papers in this field and accounts for 28.84% of the total publications with an average of 2008 publications per institutions. The top contributing Indian institution in computer science research is Anna University with 2963 publications (3.87%). This is followed by Indian Institute of Technology, Kharagpur and Indian Institute of Science, Bangalore with 2770 and 2685 publications respectively. The 4th to 11th positions are held by Indian Institute of Technology, Delhi (2393 publications), Jadavpur University (2214 publications), Indian Institute of Technology, Madras (1812), Indian Institute of Technology, Bombay (1725 publications), Indian Statistical Institute, Kolkata (1611 publications), Indian Institute of Technology, Kanpur (1553 publications), Indian Institute of Technology Roorkee (1324 publications) and Indian Institute of Technology, Guwahati (1034 publications). Thus, it was observed that the main institutes contributing in computer science research in India are IITs, IISc and few major universities.

The average citation per paper (ACPP) was calculated to be highest for Indian Statistical Institute, Kolkata (6.69 citations per paper) which was followed by Indian Institute of Science, Bangalore (5.51 citations per paper) and IIT, Delhi (5.50 citations per paper). The h-index was found to be highest for both Indian Institute of Science, Bangalore and IIT, Delhi (46 each). The h-index was 45 for Indian Statistical Institute, Kolkata and 44 for Jadavpur University.

Table 4: Top 11 Indian institutions in computer science research

Ran k	Name of Institution	TP	%	TC	ACPP	h- index
1	Anna University	2963	3.87	4745	1.60	22
2	Indian Institute of Technology, Kharagpur	2770	3.62	11886	4.29	41
3	Indian Institute of Science	2685	3.51	14787	5.51	46
4	Indian Institute of Technology, Delhi	2393	3.12	13164	5.50	46
5	Jadavpur University	2214	2.89	10603	4.79	44
6	Indian Institute of Technology, Madras	1812	2.37	7376	4.07	35
7	Indian Institute of Technology, Bombay	1725	2.25	8036	4.66	39
8	Indian Statistical Institute, Kolkata	1611	2.10	10776	6.69	45
9	Indian Institute of Technology, Kanpur	1553	2.03	7846	5.05	38
10	Indian Institute of Technology Roorkee	1324	1.73	4522	3.42	26
11	Indian Institute of Technology, Guwahati	1034	1.35	2975	2.88	24
Total of top 11 institutions		22084	28.84	96716	4.38	-
<i>TP- Total Publications, TC- Total Citations, ACPP- Average Citation per Paper</i>						

4.4 Top Sources for Publication

The top 18 sources in which more than 300 publications in computer science appeared during 2004 to 2013 are shown in table 5. The maximum Indian publications appeared in *Lecture Notes in Computer Science Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics* (4420 publications) which is followed by *Communications in Computer and Information Science* (3112 publications). Other major sources preferred by Indian authors to publish their research are *European Journal of Scientific Research* (1294 publications), *ACM International Conference Proceeding Series* (1223 publications), *Proceedings of SPIE the International Society for Optical Engineering* (1038 publications), *IEEE Region 10 Annual International Conference Proceedings* (639 publications), *Journal of Theoretical and Applied Information Technology* (595 publications), and *Journal of Computer Science* (558 publications).

S. No.	Source	No. of Publications
1	Lecture Notes in Computer Science Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics	4420
2	Communications in Computer and Information Science	3116
3	European Journal of Scientific Research	1294
4	ACM International Conference Proceeding Series	1223
5	Proceedings of SPIE the International Society for Optical Engineering	1038
6	IEEE Region 10 Annual International Conference Proceedings TENCON	639
7	Journal of Theoretical and Applied Information Technology	595
8	Journal of Computer Science	558
9	Advances in Intelligent Systems and Computing	528
10	International Journal of Advanced Manufacturing Technology	518
11	Iccet 2011 2011 3rd International Conference on Electronics Computer Technology	517
12	Advances in Intelligent and Soft Computing	513
13	IETE Journal of Research	409
14	2013 4th International Conference on Computing Communications and Networking Technologies Icccnt 2013	380
15	Applied Soft Computing Journal	348
16	Proceedings International Conference on Computational Intelligence and Multimedia Applications Iccima 2007	324
17	Defence Science Journal	317
18	Proceedings of the 2013 International Conference on Advances in Computing Communications and Informatics Icacci 2013	312

4.5 International Collaborations

India has collaborated with 128 other countries for conducting research in computer science. The top 15 countries having more than 200 collaborative papers with Indian authors are shown in table 6. India has maximum number of collaborative papers with United States (4698 papers). This is followed by United Kingdom (960 papers), Canada (807 papers), Germany (696 papers) and France (683 papers).

Indian Institute of Science, Bangalore has the highest number of international collaborative publications (603 papers). This is followed by Indian Institute of Technology, Delhi (582 papers), Indian Institute of Technology, Kharagpur (464 papers), Indian Statistical Institute, Kolkata (439 papers), Indian Institute of Technology, Kanpur (418 papers), Indian Institute of Technology, Bombay (417 papers) and Jadavpur University (415 papers).

S. No.	Country	Collaborative Papers
1	United States	4698
2	United Kingdom	960
3	Canada	807
4	Germany	696
5	France	683
6	Australia	569
7	Singapore	523
8	South Korea	495
9	Japan	439
10	Italy	409
11	China	302
12	Malaysia	277
13	Norway	241
14	Switzerland	230
15	Spain	225

4.6 Most Prolific Indian Authors

On the basis of publication output data for India in computer science a total of 26 authors were identified as high productive ones publishing between 100 and 222 papers. The most prolific Indian author in computer science in terms of publications is S. Das of Indian Statistical Institute, Kolkata with 222 publications. Other prominent Indian authors in computer science are A. Konar of Jadavpur University, Kolkata (182 publications), K. Deb of IIT, Kanpur (163 publications), L.M. Patnaik of IISc, Bangalore (156 publications), C.V. Jawahar of CVIT, Hyderabad (149 publications), S. Nandi of IIT, Guwahati (148 publications) and P. Gupta of IIT, Kanpur (143 publications).

Among these 26 high productive authors 4 are affiliated with Indian Statistical Institute, Kolkata, 3 are affiliated with IIT, Delhi, 2 each are affiliated with IISc, Bangalore, IIT, Kanpur, Anna University, Chennai and Jadavpur University, Kolkata and 1 each with BARC, Mumbai, CVIT, Hyderabad, Indian Institute of Engineering Science and Technology, Shibpur, IIT, Bhubaneswar, IIT, Bombay, IIT, Guwahati, IIT, Hyderabad, IIT, Kharagpur, IIT, Roorkee, Institute of Mathematical Sciences, Chennai and University of Delhi, Delhi.

The ACPP is highest for S. Bandyopadhyay (15.80), followed by S. Das (14.53) and S.K. Pal (12.27). S. Das has the highest h-index of 26. He is followed by S. Bandyopadhyay and S.K. Pal with h-index of 20 each.

Table 7: Most prolific Indian authors in computer science

S. No.	Author	Affiliation	TP	TC	ACPP	h-index
1	Das, S.	Indian Statistical Institute, Kolkata	222	3225	14.53	26
2	Konar, A.	Jadavpur University, Kolkata	182	1287	7.07	14
3	Deb, K.	Indian Institute of Technology, Kanpur	163	1769	10.85	19
4	Patnaik, L.M.	Indian Institute of Science, Bangalore	156	423	2.71	9
5	Jawahar, C.V.	CVIT, Hyderabad	149	346	2.32	10
6	Nandi, S.	Indian Institute of Technology, Guwahati	148	214	1.45	8
7	Gupta, P.	Indian Institute of Technology, Kanpur	143	430	3.01	10
8	Vaidehi, V.	Anna University, Chennai	136	172	1.26	6
9	Venugopal, K.R.	Bhabha Atomic Research Centre, Mumbai	132	165	1.25	6
10	Pal, U.	Indian Statistical Institute, Kolkata	126	701	5.56	12
11	Chaudhury, S.	Indian Institute of Technology, Delhi	126	305	2.42	7
12	Desai, U.B.	Indian Institute of Technology, Hyderabad	120	305	2.54	8
13	Pal, S.K.	Indian Statistical Institute, Kolkata	116	1423	12.27	20
14	Merchant, S.N.	Indian Institute of Technology, Bombay	114	270	2.37	8
15	Nasipuri, M.	Jadavpur University, Kolkata	111	289	2.60	9
16	Bandyopadhyay, S.	Indian Statistical Institute, Kolkata	111	1754	15.80	20
17	Panigrahi, B.K.	Indian Institute of Technology, Delhi	109	640	5.87	13
18	Misra, S.	Indian Institute of Technology, Kharagpur	108	645	5.97	15
19	Panda, G.	Indian Institute of Technology, Bhubaneswar	107	502	4.69	12
20	Pant, M.	Indian Institute of Technology, Roorkee	105	360	3.43	10
21	Rahaman, H.	Indian Institute of Engineering	103	119	1.16	5

		Science and Technology, Shibpur				
22	Kannan, A.	Anna University, Chennai	103	147	1.43	5
23	Rajan, B.S.	Indian Institute of Science, Bangalore	102	865	8.48	14
24	Hanmandlu, M.	Indian Institute of Technology, Delhi	102	521	5.11	12
25	Bedi, P.	University of Delhi, Delhi	100	212	2.12	6
26	Saurabh, S.	Institute of Mathematical Sciences, Chennai	100	595	5.95	13

TP- Total Publications, TC- Total Citations, ACPP- Average Citation per Paper

4.7 Citation Profile and Highly Cited Papers

Out of the total 76597 documents published by India in computer science during 2004 to 2013 citations were received by 42.44% documents and the rest 57.56% were not cited at all. Among the documents which were cited, 118 documents received more than 100 citations and 314 documents received citations more than 50 but less than 100 citations. Table 7 list the 28 highly cited papers which have received more than 200 citations. Among these only one paper is single authored and the rest have two or more authors. These papers have been published in 24 different national and international journals and conference proceedings. Out of these 28 papers, 6 papers were published in 2004, 3 in 2005, 4 each in 2006 and 2007, 3 each in 2008 and 2009, 2 each in 2010 and 2011 and 1 in 2012. These papers received a total of 9284 citations with an average of 331.57 citations per paper. Ten papers have more citations than this average. The most cited article is published in S. Das and P.N. Suganthan in *IEEE Transactions on Evolutionary Computation* in the year 2011.

Table 8: Highly cited papers

S. No.	Year	Document Title	Author/s	Source Title	No. of citations
1	2011	Differential evolution: A survey of the state-of-the-art	Das S., Suganthan P.N.	IEEE Transactions on Evolutionary Computation	735
2	2010	Recent advances and industrial applications of multilevel converters	Kouro S., et al	IEEE Transactions on Industrial Electronics	621
3	2007	Gesture recognition: A survey	Mitra S., Acharya T.	IEEE Transactions on Systems, Man and Cybernetics Part C: Applications and Reviews	493
4	2010	A survey on cascaded multilevel inverters	Malinowski M., Gopakumar K., Rodriguez J., Perez M.A.	IEEE Transactions on Industrial Electronics	438
5	2006	Capacity scaling laws in MIMO relay networks	Bolskei H., Nabar R.U., Oyman O., Paulraj A.J.	IEEE Transactions on Wireless Communications	411

6	2009	Differential evolution using a neighborhood-based mutation operator	Das S., Abraham A., Chakraborty U.K., Konar A.	IEEE Transactions on Evolutionary Computation	387
7	2006	Heart rate variability: A review	Acharya U.R., Joseph K.P., Kannathal N., Lim C.M., Suri J.S.	Medical and Biological Engineering and Computing	379
8	2009	Cuckoo search via Levy flights	Yang X.-S., Deb S.	2009 World Congress on Nature and Biologically Inspired Computing, NABIC 2009 - Proceedings	373
9	2011	A survey on security issues in service delivery models of cloud computing	Subashini S., Kavitha V.	Journal of Network and Computer Applications	351
10	2008	On some aspects of variable selection for partial least squares regression models	Roy P.P., Roy K.	QSAR and Combinatorial Science	336
11	2005	A possibilistic fuzzy c-means clustering algorithm	Pal N.R., Pal K., Keller J.M., Bezdek J.C.	IEEE Transactions on Fuzzy Systems	329
12	2006	Image encryption using chaotic logistic map	Pareek N.K., Patidar V., Sud K.K.	Image and Vision Computing	327
13	2008	Dielectric Materials for Wireless Communication	Sebastian M.T.	Dielectric Materials for Wireless Communication	317
14	2004	DakNet: Rethinking Connectivity in Developing Nations	Pentland A., Fletcher R., Hasson A.	Computer	301
15	2004	Identification of humans using gait	Kale A., et al	IEEE Transactions on Image Processing	280
16	2007	A 5-GHz mesh interconnect for a teraflops processor	Hoskote Y., Vangal S., Singh A., Borkar N., Borkar S.	IEEE Micro	271
17	2004	LDPC block and convolutional codes based on circulant matrices	Tanner R.M., Sridhara D., Sridharan A., Fuja T.E., Costello Jr. D.	IEEE Transactions on Information Theory	271
18	2004	A dynamic ID-based remote user authentication scheme	Das M.L., Saxena A., Gulati V.P.	IEEE Transactions on Consumer Electronics	263

19	2004	Managing cross-cultural issues in global software outsourcing	Krishna S., Sahay S., Walsham G.	Communications of the ACM	262
20	2005	Geometric homogeneity with applications to finite-time stability	Bhat S.P., Bernstein D.S.	Mathematics of Control, Signals, and Systems	258
21	2005	A hybrid least square-fuzzy bacterial foraging strategy for harmonic estimation	Mishra S.	IEEE Transactions on Evolutionary Computation	256
22	2004	Validity index for crisp and fuzzy clusters	Pakhira M.K., Bandyopadhyay S., Maulik U.	Pattern Recognition	254
23	2007	Twin support vector machines for pattern classification	Jayadeva, Khemchandani R., Chandra S.	IEEE Transactions on Pattern Analysis and Machine Intelligence	245
24	2006	Bounds for multihop relayed communications in Nakagami-m fading	Karagiannidis G.K., Tsiftsis T.A., Mallik R.K.	IEEE Transactions on Communications	245
25	2009	Optimization of cooperative spectrum sensing with energy detection in cognitive radio networks	Zhang W., Mallik R.K., Ben Letaief K.	IEEE Transactions on Wireless Communications	231
26	2008	Automatic clustering using an improved differential evolution algorithm	Das S., Abraham A., Konar A.	IEEE Transactions on Systems, Man, and Cybernetics Part A: Systems and Humans	223
27	2012	Modeling and analysis of K-tier downlink heterogeneous cellular networks	Dhillon H.S., Ganti R.K., Baccelli F., Andrews J.G.	IEEE Journal on Selected Areas in Communications	218
28	2007	Multi-Objective Particle Swarm Optimization with time variant inertia and acceleration coefficients	Tripathi P.K., Bandyopadhyay S., Pal S.K.	Information Sciences	209

4. Summary and Conclusions

The analysis of computer science publications data from 2004 to 2013 obtained using Scopus database reveals that China and United States accounts for 40% of the world publications in computer science. India stands at ninth place with 76597 publications during 2004 to 2013 and accounts for 3.32% of the total world publications. Among these Indian publications, more than half were published during 2011 to 2013 indicating a steep increase during these years. Among the Indian institutions, Anna University has published the maximum number of publications in computer science. However in terms

of h-index and Average Citation per Paper (ACPP) the leading institutions are Indian Statistical Institute, Kolkata, Indian Institute of Science, Bangalore and IIT, Delhi. The maximum Indian publications in computer science appeared in *Lecture Notes in Computer Science Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics*. S. Das of Indian Statistical Institute, Kolkata is the most prolific author with 222 publications during 2004 to 2013 and also has the highest h-index of 26. India has collaborated with 128 countries for computer science publications, the maximum being with United States (4698 publications). Of the total Indian publications in computer science during 2004 to 2013, 42.44% have been cited by others. There are 118 publications by Indian authors which have been cited more than 100 times indicating the quality of these publications by these authors.

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